Journal of Electromyography and Kinesiology 25 (2015) 966–972

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Older adults utilize less efficient postural control when performing pushing task

Yun-Ju Lee *, Bing Chen, Alexander S. Aruin

University of Illinois at Chicago, Chicago, IL 60612, United States

ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form 14 August 2015
Accepted 3 September 2015

Keywords:
Aging
Anticipatory
Compensatory
Muscle activity
Pushing

ABSTRACT

The ability to maintain balance deteriorates with increasing age. The aim was to investigate the role of age in generation of anticipatory (APA) and compensatory (CPA) postural adjustments during pushing an object. Older (68.8 ± 1.0 years) and young adults (30.1 ± 1.4 years) participated in the experiment involving pushing an object (a pendulum attached to the ceiling) using both hands. Electrical activity of six leg and trunk muscles and displacements of the center of pressure (COP) were recorded and analyzed during the APA and CPA phases. The onset time, integrals of muscle activity, and COP displacements were determined. In addition, the indexes of co-activation and reciprocal activation of muscles for the shank, thigh, and trunk segments were calculated. Older adults, compared to young adults, showed less efficient postural control seen as delayed anticipatory muscle onset times and delayed COP displacements. Moreover, older adults used co-activation of muscles during the CPA phase while younger subjects utilized reciprocal activation of muscles. The observed diminished efficiency of postural control during both anticipatory and compensatory postural adjustments observed in older adults might predispose them to falls while performing tasks involving pushing. The outcome provides a background for future studies focused on the optimization of the daily activities of older adults.

1. Introduction

Age is an important factor affecting the ability to maintain standing posture while performing voluntary arm movements (Bleuse et al., 2006; Carvalho et al., 2010; Kubicki et al., 2012) or dealing with external impacts to the body (Bugnariu and Sveistrup, 2006; Kanekar and Aruin, 2014a,b). Both arm movements and external impacts induce body perturbations and require implementation of the anticipatory and compensatory postural strategies to maintain and restore balance. Anticipatory postural adjustments (APA) are a feed-forward control mechanism, which reflects changes in the activity of postural muscles prior to the expected postural perturbations (Aruin and Latash, 1995, 1996; Belen'kii et al., 1967; Massion, 1992). The compensatory postural adjustments (CPA) is a feedback-based control mechanism, which reflects changes in muscle activity during the balance restoration phase following the perturbations (Alexandrov et al., 2005; Macpherson et al., 1989; Maki and McIlroy, 2006; Park et al., 2004).

Pushing, which involves using upper extremities exerting force away from the body, is the activity people commonly use in daily life for example, while moving strollers or grocery carts; it is also used by older adults pushing a wheeled walker with a seat while ambulating. Furthermore, aerobic activity involving for example, pushing a lawn mower, has beneficial effects on health outcomes for older adults (Elsawy and Higgins, 2010). However, how older adults perform daily activity involving pushing was not reported. Moreover, pushing tasks involve force exertion performed simultaneously with maintenance of balance, which could be challenging for the older adults. In addition, efficient pushing requires well-organized postural control utilizing both anticipatory and compensatory postural strategies (Lee and Aruin, 2013). It was reported that older adults performing pushing exhibited different compared to young adults distal-to-proximal postural response (Inglin and Woollacott, 1988) and higher amplitude of center of pressure (COP) excursions (Blaszczyk et al., 1997). It was also suggested that physical activities involving pushing could be a risk factor for falls and fractures in the elderly (Palvanen et al., 2000).

The role of age in the generation of anticipatory postural adjustments was studied during performance of pull-and-push arm movements (Blaszczyk et al., 1997; Inglin and Woollacott, 1988; Stelmach et al., 1990), arm raising movements (Bleuse et al.,

* Corresponding author at: Department of Physical Therapy (MC 898), University of Illinois at Chicago, 1919 W. Taylor St., Chicago, IL 60612, United States. Tel.: +1 (312) 355 0902; fax: +1 (312) 996 4583.
E-mail address: leeyunju@uic.edu (Y.-J. Lee).

http://dx.doi.org/10.1016/j.jelekin.2015.09.002
1050-6411/

2006; Carvalho et al., 2010; Kubicki et al., 2012), or externally induced perturbations (Kanekar and Aruin, 2014b). It was reported that when older and young adults were exposed to external perturbations, ventral and dorsal postural muscles of older adults were activated during the APA phase about 50–80 ms later than the muscles of young adults (Kanekar and Aruin, 2014b). Moreover, the COP displacements were seen 100 ms later in older adults during both self- and externally-triggered perturbations (Bugnariu and Sveistrup, 2006; Kanekar and Aruin, 2014b).

Studies of compensatory postural adjustments using external perturbations applied to the upper body revealed that magnitudes of muscle activity and COP displacements in older adults were significantly larger than in young participants (Claudino et al., 2013; Kanekar and Aruin, 2014a). However, postural control of older adults performing tasks involving pushing an object is not well understood. Therefore, the objective of this study was to investigate effects of age on anticipatory and compensatory postural adjustments when performing a pushing task. Moreover, prior literature suggests that the central nervous system (CNS) controls muscles as task-specific structural units and not at a single muscle level (Bernshtein, 1967; Slijper and Latash, 2000, 2004). Additionally, since the CNS uses either reciprocal activation or co-activation of ventral and dorsal muscles for postural control, sum and difference between ventral and dorsal muscle activities characterizing co-activation (*C* value) and reciprocal activation (*R* value) of postural muscles respectively (Slijper and Latash, 2004) could be used to describe postural control. Furthermore, postural sway in older adults increase with the increase of the task demands (Prioli et al., 2006) and larger COP displacements were observed during both anticipatory and compensatory phases of postural control in older adults exposed to external perturbations (Claudino et al., 2013; Kanekar and Aruin, 2014b). Hence, our first hypothesis was that the activation of leg and trunk muscles and COP displacements will be delayed in older adults compared to young subjects. Secondly, we hypothesized that older adults will control muscle activity using co-activation pattern with larger COP displacement while young adults will utilize pattern of reciprocal activation of muscles with smaller COP displacement during the anticipatory phase (APAs) and the compensatory (CPAs) phase of postural control when performing the pushing task.

2. Methods

2.1. Participants

Eight older adults (4 males and 4 females) and eight young adults (5 males and 3 females) without any neurological or musculoskeletal disorders participated in the study. All participants had normal or corrected to normal vision and were able to understand and follow instructions. Older adults were independent community ambulators, were not on any sedative medications, and had not undergone any surgery in the six months prior to study participation. The mean (SE) age of the older group was 68.8 ± 1.0 years, the mean height was 1.73 ± 0.03 m, and the mean body mass was 64.9 ± 6.8 kg. The mean (SE) age of the young group was 30.1 ± 1.4 years, the mean height was 1.73 ± 0.02 m and the mean body mass was 73.9 ± 4.6 kg. Both, body height and mass were not significantly different between the two groups. All subjects signed a written informed consent approved by the Institutional Review Board of the University of Illinois at Chicago.

2.2. Experimental procedure

The subjects were required to stand on a force platform (Model OR-5, AMTI, USA) in front of an aluminum pendulum (affixed to the ceiling) and push the horizontal flat wooden handle (62 × 9 × 2 cm) attached to it. An extra load (30% body mass) was fastened to the opposite side of the handle. The subjects were instructed to stand upright with feet shoulder width apart. Their upper arms were by the sides of their trunk at 90 degrees of elbow flexion and wrist extension, and palms slightly contacting the wooden handle. The height of the pendulum was adjusted to match the subject's hand position (Fig. 1). The subjects were instructed to push the pendulum handle straight forward with both hands using only trunk motion without wrist flexion and elbow extension as well as without taking a step or lifting the heels from the surface of the force platform. The subjects performed each trial in a self-paced manner after receiving the experimenter's command "push." After the pendulum was pushed away, it was caught by the experimenter. Then, the subjects returned to the starting position and waited for the experimenter's command to perform the next trial (5 trials in total). All the subjects were provided with several practice trials to familiarize themselves with the task. The study was conducted during one session that lasted approximately 20 min.

2.3. Data collection

The electrical activity of muscles (EMG) was recorded using disposable surface electrodes (Red Dot, 3M, USA). After cleaning the skin with alcohol, electrodes were attached to the bellies of the following muscles: tibialis anterior, TA (at one-third on the line between the tip of the fibula and the tip of the medial malleolus), medial gastrocnemius, MG (on the most prominent bulge of the muscle), rectus femoris, RF (at 50% on the line from the anterior superior iliac spine to the superior part of the patella), biceps femoris, BF (half way between the ischial tuberosity and the lateral epicondyle of the tibia), rectus abdominis, RA (3 cm lateral to the

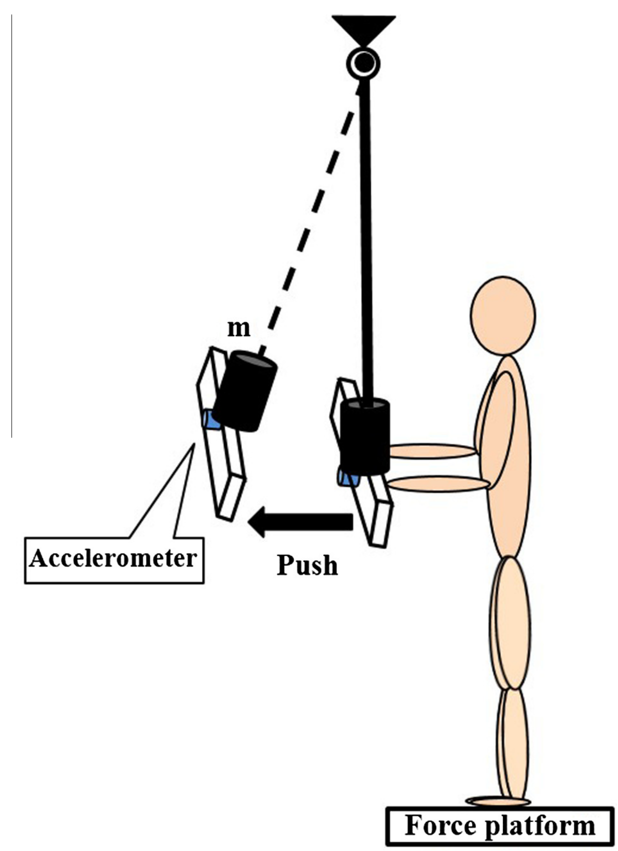

Fig. 1. The schematic representation of the experimental setup. *m* – is the additional weight attached to the pendulum.